VOLUME 79 SEPARATE No. 267

PROCEEDINGS

AMERICAN SOCIETY
OF
CIVIL ENGINEERS

SEPTEMBER, 1953

ALGAE RESPONSIBLE FOR ODOR AND TASTE IN PUBLIC WATER SUPPLIES

by George J. Turre

SANITARY ENGINEERING DIVISION

{Discussion open until January 1, 1954}

Headquarters of the Society
33 W. 39th St.
New York 18, N. Y.

PRICE $0.50 PER COPY

THIS PAPER

--represents an effort of the Society to deliver technical data direct from the author to the reader with the greatest possible speed. To this end, it has had none of the usual editing required in more formal publication procedures.

Readers are invited to submit discussion applying to current papers. For this paper the final closing dead line appears on the front cover.

Those who are planning papers or discussions for "Proceedings" will expedite Division and Committee action measurably by first studying the printed directions for the preparation of ASCE technical papers. For free copies of these directions—describing style, content, and format—address the Manager, Technical Publications, ASCE.

This paper was published at 1745 S. State Street, Ann Arbor, Mich., by the American Society of Civil Engineers. Editorial and General Offices are at 33 West Thirty-ninth Street, New York 18, N. Y.

ALGAE RESPONSIBLE FOR ODOR AND TASTE IN PUBLIC WATER SUPPLIES

George J. Turre, Sanitary Engineer
Board of Water Commissioners, Denver, Colorado

Odor and taste in public water supplies, due to natural causes, may be produced by decomposed organic matter, mineral substances or hydrogen sulfide. The most common origin of odor and taste in water supplies is due to the presence of plant growth of the algae type. Algae are simple forms of plant life; most species require warm temperature and sunlight, and, in addition, suitable food for their development. Algae spores of the organisms are transported through the air by wind, by animals, or by physical means in the same manner as bacteria, yeast, or other plant seeds. Most algae are microscopic in size. They vary in size and shape from a single cell to filaments, chains or group of cells. There are thousands of species of algae, possessing various colors,--red, brown, yellow or green. It is impossible to become acquainted with more than a few of the most prominent species which are responsible for odor and taste in water supplies.

For a full detailed study of algae, identification, enumeration, and methods of control, reference is made to two comprehensive books: "Microscopy of Drinking Water" by G. C. Whipple published by John Wiley and Sons, New York; and, "The Use of Copper Sulfate in Control of Microscopic Organisms" by Frank E. Hale, Ph. D., published by the Phelps Dodge Refining Corp., New York.

Effects of Algae:

The most important effect of algae in public water supplies is the odor and taste which they may cause. The living organisms secrete and excrete substances which impart objectionable odors and tastes to the surrounding water. Small amounts of chlorine used in the disinfection of water will often liberate distasteful oils of the plant growth. Large amounts of organisms will cause an unsightly turbidity, clogging of filter beds, inhibit proper floc formation, reduction in filtration rates, reduction of flow rates in pipelines, and staining of plumbing fixtures.

From a health standpoint, algae are not significant; they do not cause disease in man or in higher animals. An unusually heavy amount of the common microscopic organisms occurring in drinking water can, however, conceivably produce nausea or digestive disturbances by water users. Water of this character would generally be too offensive to consume without treatment.

Most species of algae grow in the presence of sunlight through the process of photosynthesis--obtaining their food from dissolved gases and mineral salts normally present in water, Therefore it is very important, where practical, to have all filtered-water storage reservoirs covered to exclude the sunlight.

The distinctive odors produced by algae are grouped under three general terms: Aromatic, Grassy, and Fishy.

Aromatic Odors: Aromatic odors are due chiefly to Diatomaceae. The Strongest odor is that produced by Asterionella. The character of this odor ranges in its intensity. When few organisms are present, the water may have an aromatic odor; as they increase, the odor resembles that of a rose geranium; when they are abundant, the odor becomes fishy and nauseating.

Grassy Odors: Grassy odors are produced largely by Cyanophyceae. Anabaena is the common offender in this group. There are two species which have slightly different odors. The grassy odor is usually accompanied by a moldy odor, due to decaying of the organism. A pig-pen odor is imparted in extreme cases.

Fishy Odors: Fishy odors are perhaps the most disagreeably of any detected in drinking water. Water, rich in Uroglena, often imparts a cod liver odor. Volvox, Eudorina, and Pandorina also produce a fishy odor.

For all practical purposes, algae are commonly divided into six groups:

Group 1. Diatomaceae. Diatoms comprise a large number of organisms which are chiefly one-celled plants; the wall material being inclosed in a beautifully marked cell wall of tough silicious substance. These markings take the apparent form of dots and ridges, some of which are coarse so that they may be resolved by low-power lenses of the microscope, while some are so fine as to almost defy the resolving power of the highest aperature oil-immersion objectives. Diatoms, which existed ages ago and whose silicious parts settled in lake beds, formed the diatomaceous earth which is used commercially as an ingredient in silver polish, tooth paste, and insulation material. In addition to their green coloring matter (Chlorophyl), diatoms also have a brownish coloring matter, which is easily observed under a microscope.

Diatoms reproduce by cell splitting. Asterionella, a star-shaped organism found in lakes and reservoirs, is a common example. The dead organism (Asterionella) causes aromatic, fishy or geranium odors. Synedra, another example, often found in reservoirs, produces an earthy odor.

The first diatoms were described in 1800. Since that time over 15,000 forms have been described and classified. Diatoms live wherever there is sunlight and moisture. The high degree of perfection used in present-day microscope lenses is due to the use of fossil diatoms, as "test objects" by early workers in that field.

It is interesting to consider the importance of the role played by living diatoms in the food cycle of the higher forms of life, including man. They are the "Grass of the Sea." Like all green plants, these minute cells manu facture their food from inorganic materials; and then are themselves eaten by a host of small animals, such as protozoas, hydra, worms, rotifers and crustacea. These then serve as food for larger animals: Intertebrates, fish-fry and tadpoles which, in turn, are eaten by still larger aquatic forms as bullfrogs, large fish, and whales--the cycle ending in man when he eats fish. Thus diatoms constitute one of the largest and most fundamental groups standing at the base of the food pyramid, synthesizing inorganic minerals into organic for an important portion of the earth's inhabitants.

Group 2. Cyanophyceae. These often form a dark green froth on the water surface, and is referred to as "Water Bloom." There are several species often found in the summer months, but they have been found in the winter months, growing under the ice. They may grow in polluted water, or water containing considerable organic matter. They are blue-green in color, free-floating, or in gelatinous masses or strata, have single cells, filaments or chains. Some are beadlike in structure and do not necessarily have

a definite cell structure. Common species are Anabaena and Aphanizomenon, which produce a grassy odor and taste, and often a vile pig-pen odor will be imparted.

Group 3. Chlorophyceae. This group comprises a large number of species, green in color, characterized by the presence of chlorophyl. They comprise a wide range of organisms, from single cells to multicellular and flagellate forms. They reproduce asexually or sexually. This group includes thousands of forms, from stringy filaments so frequently found attached to walls and sides of tanks and open channels to single free-floating forms. Volvox is an example of this group. It is a cross between a plant and an animal; Spirogyra, which forms a stringy mass near the surface of water. It produces a vegetable odor. Odors produced by many forms of this group vary from grassy to fishy.

Group 4. Protozoa. These are the lowest form of animal life. Many forms are on the borderline between plants and animals, possessing some characteristics of both. They are unicellular in stuucture though they may gather into colonies; Dinobryon, which often produces an aromatic or fishy odor and taste; Synura, which imparts a cucumber, fishy bitter taste, are examples of this group.

Group 5. Schizomycetes. These are bacteria closely allies to the algae. Examples are Beggiatoa or " Sulfur Bacteria ", which cause a decayed hydrogen-sulfide odor; and the Crenothrix or " Iron Bacteria ", which also cause an offensive decayed odor.

Group 6. Fungi. These are flowerless plants, lacking in chlorophyl and starch. They are seldom found in clean water, are common in sewage or in other organic wastes. They will grow in the absence of sunlight.

It is evident, therefore, that knowledge, recognition and the control of algae in public water supplies is of great importance to sanitary engineers, and others in charge of public water supplies. It is not only their duty and responsibility to furnish safe water from the bacteriological standpoint, but they should also furnish water free from odor and taste.

The purpose of this paper is to present actual photomicrographs of some of the most troublesome algae, which the author has encountered in the microscopical examination of surface waters of the State of Colorado. Particular reference is made to those organisms which have produced odor and taste in drinking water.

Photomicrographs of some of the different genera of microscopic organisms found in public water wupplies, responsible for odor and taste.

DIATOMACEAE

No. 1 Asterionella. (400x) (Little Star). This organism when present in sufficient numbers (500 standard units or more) will impart an aromatic, geranium odor during the process of cell splitting or reproduction. In larger numbers they may give the water a fishy odor. They are brownish in color and prevalent in the spring and fall months. The organisms are fragile, may cause trouble by penetrating filter material, and by inhibiting proper floc formation.

No. 2 Synedra. (400x) This organism resembles a fine tooth comb. The sides are straight, almost parallel. It contains a silicious substance, is brown in color, often inhibits proper floc formation, and will impart an earthy odor. Prevalent in the spring and summer months.

No. 3 Stephanodiscus. (200x) Brown in color, resembles old fashioned pill box. Note the marginal teeth. Odor may be fishy, aromatic or geranium. In large numbers will clog filter beds, resulting in the shortening of filter runs. Prevalent in the spring and fall months.

No. 4 Fragilaria. (80x) Rectangular cells attached side by side. This shows girdle view. It has an aromatic odor. Usually present in the spring and summer months.

No. 5 Surirella. (400x) Valve view. Cells of Surirella are usually found solitary and free floating. There are many species.

No. 6 Stauroneis. (180x) Valve view. Cells are similar to Navicula. There are many species. They possess a backward and forward motion and are easily recognized because of the stauros.

No. 7 Melosira. (200x) Golden brown in color. Strong musty odor in presence of chlorine. Organism appears in long cylindrical filament. This Melosira is attached to an unidentified organism (probably protosoan).

CYANOPHYCEAE

No. 8 Anabaena. (120x) Circinalis species, appearing like a string of beads. Color brownish-green, or brown. Found free-floating. Vegetative cells spherical. Filaments are without sheaths. Imparts a grassy odor and taste. When present in large numbers, it imparts a vile pig pen odor. Prevalent in the summer months. This organism is one of the common trouble makers; it is easily destroyed with a dose of one pound of copper sulfate per million gallons of water.

No. 9 Anabaena. (120x) Flos-aquae species. Appears like a curled spring. Odor and taste produced may be characterized as moldy, grassy, nasturtium, or pig pen. This species is prevalent in the summer months.

No. 10 Aphanizomenon. (120x) Appears in attached masses like a sheaf of wheat. Found free-floating. Spores are long and oval. Filaments are tapered; will easily clump together. Contains blue-green coloring matter; a moldy, grassy, vile, offensive odor is imparted. Prevalent in the summer months.

CHLOROPHYCEAE

No. 11 Spirogyra. (120)) A green alga containing chlorophyl in spiral bands.

Conjugation is one means of reproduction. Bright green in color. There are many species. Cells are generally cylindrical and attach themselves to form masses. Found free-floating near the surface of water. Grassy odor is imparted. Prevalent in the summer months.

No. 12 Spirogyra. (280x) Shows organism under higher magnification.

No. 13 Scenedesmus. (400x) Shows cells in lateral contact, in one or more rows. Cell numbers in multiples of two; green in color, odor imparted, grassy.

No. 14 Pediastrum. (400x) Shows a fine specimen. Resembles a gear wheel; found free-floating; Will produce faint grassy odor. Prevalent in the summer months.

No. 15 Pediastrum. (100x) Shows a different specie; a grassy odor may be imparted when present in large numbers.

No. 16 Staurastrum. (400x) Cell wals are similar to Cosmarium in front view, but are angular in end view; Chlorophyl, located in center of semi-circle cells. Organism produces a grassy odor; prevalent in the summer months.

No. 17 Volvox. (25x) This organism is perhaps one of the most beautiful forms to observe under the low power of the microscope. Number of cells are arranged in clusters located just within the periphery of a gelatinous sheath. Number of cells vary from two hundred to many thousands. Organism has a rolling motion, often visible to the naked eye. Fishy odor and taste imparted. Prevalent in the summer months.

No. 18 Pandorina. (120x) Organism contains an even number of cells, 16 to 32. Colonies are motile, resembles a hollow sphere. Colony is enclosed in a copious hyaline, gelatinous sheath. Organism is very resistant to chemical treatment, especially with copper sulfate. Faint fishy odor and taste imparted. Prevalent in the summer months.

No. 19 Cosmarium. (200x) Cell is oblong, cylindrical, eliptical or orbicular; ends are truncated or rounded. Chlorophyl, is concentrated in center of semi-cells; organism imparts a grassy odor. Prevalent in the summer months.

No. 20 Cosmarium. (200x) Photo shows conjugation.

No. 21 Ceratium. (120x) (This organism resembles a turkey's foot). It is found free-floating; contains horn-like elongations. Brown in color. Can easily penetrate filter material. There are several species. Will impart a vile fishy odor. Prevalent in the summer and fall months.

No. 22 Actinophyrs. (150x) This organism is known as the "sun Animalcule", common in swamp waters. Has a blackish white mottled appearance; may produce a fishy odor.

No. 23 Codonella. (200x) (Jug shaped organism). Very active; free-swimming. Surface of organism covered with a fine vibratile cilia. Fishy odor imparted when organism is present in large numbers. Prevalent in the summer months.

CRUSTACEA

No. 24 Cyclops. (120x) Very common specie. Large enough to observe

without the use of a microscope. Single large eye in the foremost part of the body. Its movement is a peculiar jerky motion. Prevails abundantly in the spring and summer months. Very resistant to the copper sulphate treatment. Makes excellent fish food; delicate flavor of trout is attributed to the diet on crustacea. May impart a fishy odor when present in large numbers, may also reduce filter runs.

No. 25 Daphnia. (120x) Another common specie of Crustacea, often found near surface of water. Will impart a fishy odor when present in large numbers. Prevalent in the spring and summer months. May reduce filter runs.

No. 26 Method of applying copper sulfate to a small reservoir for the control of algae. (Long Lake Reservoir, Denver Water System).

No. 27 Method of applying copper sulfate to a large reservoir for the control of algae. (Marston Lake, Denver Water System).

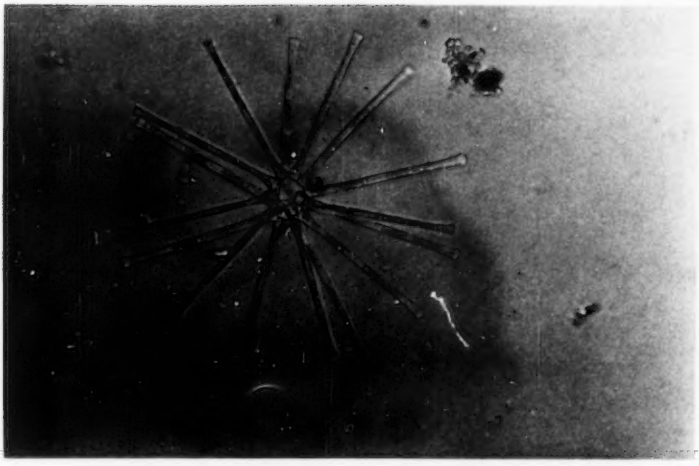

Fig. 1 Asterionella (400 X)

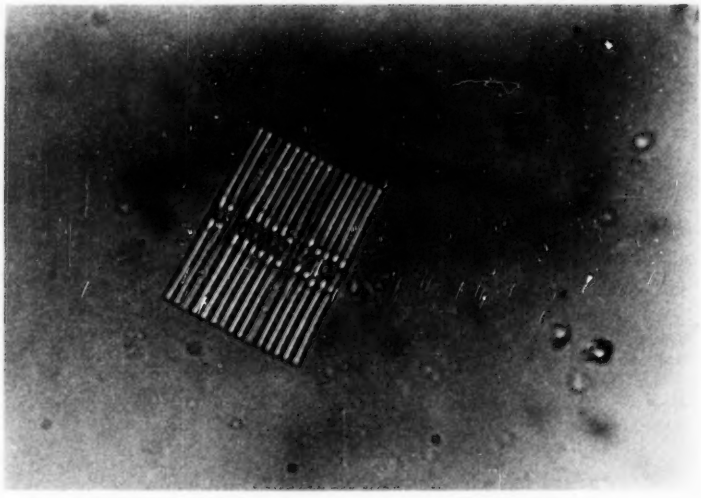

Fig. 2 Synedra (400 X)

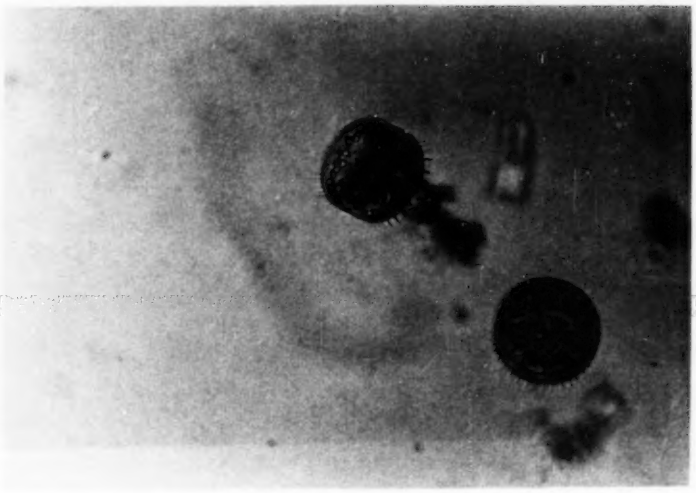

Fig. 3 Stephanodiscus (200 X)

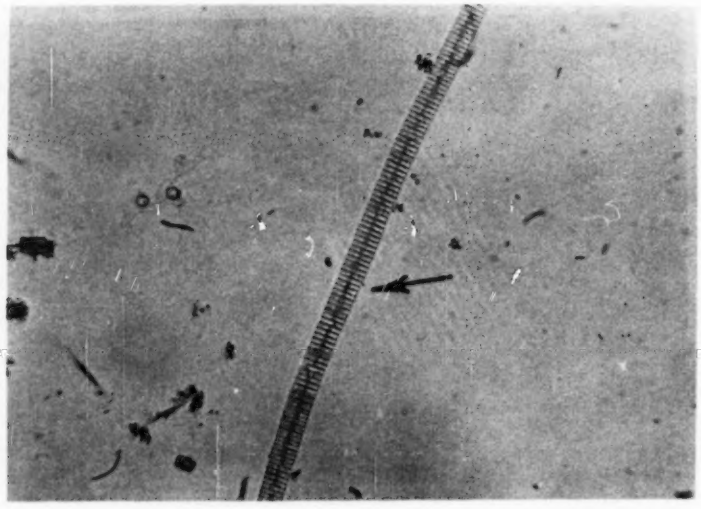

Fig. 4 Fragilaria (800 X)

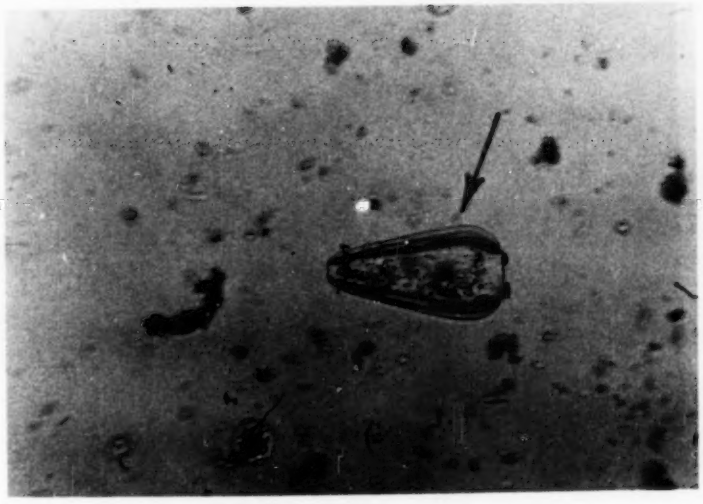

Fig. 5 Surirella (400 X)

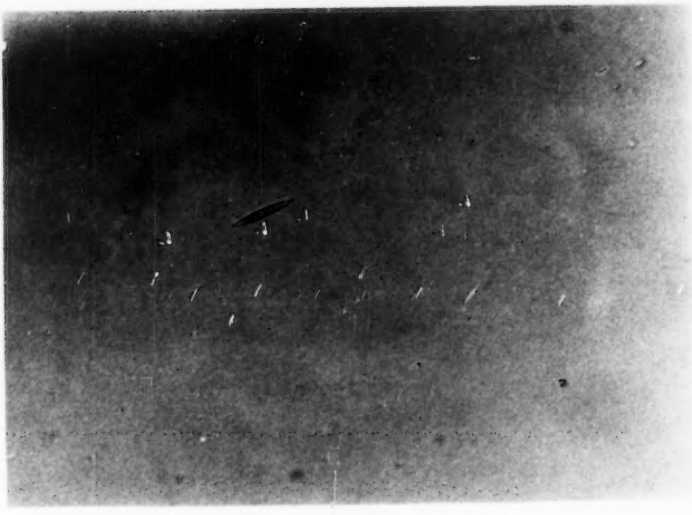

Fig. 6 Stauroneis (180 X)

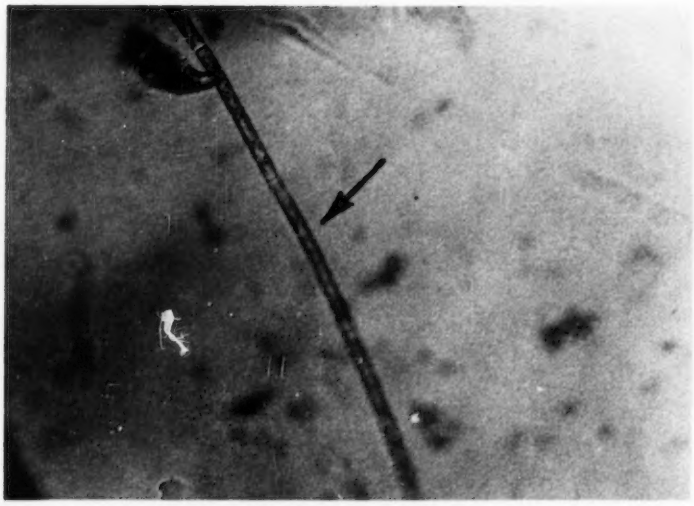

Fig. 7 Melosira (200 X)

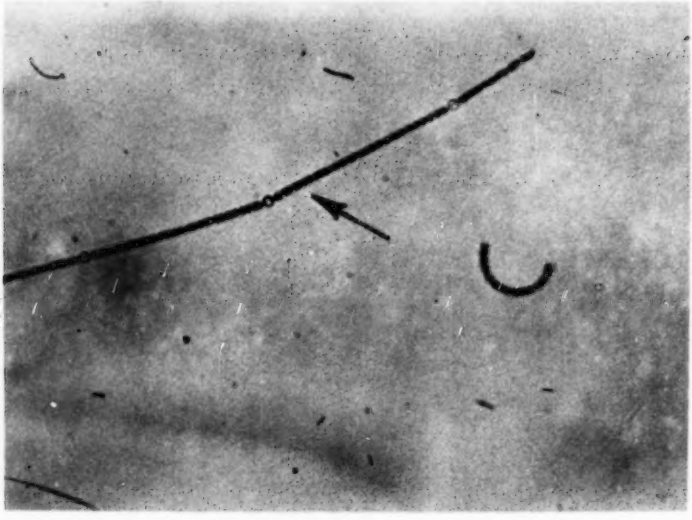

Fig. 8 Anabaena (120 X)

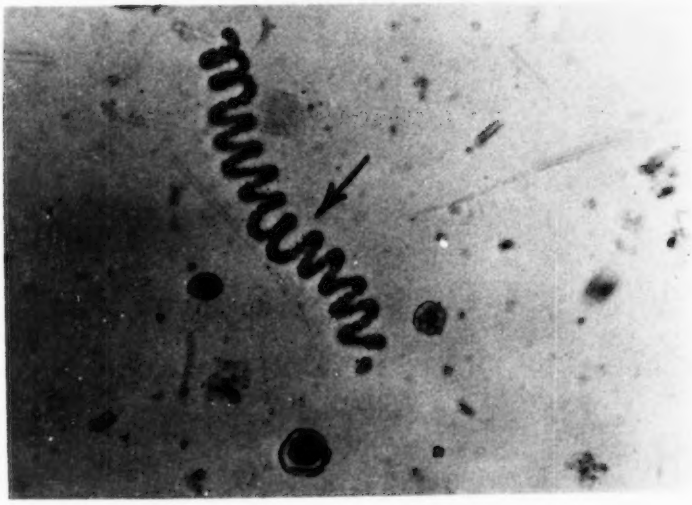

Fig. 9 Anabaena (Flos-aquae) (120 X)

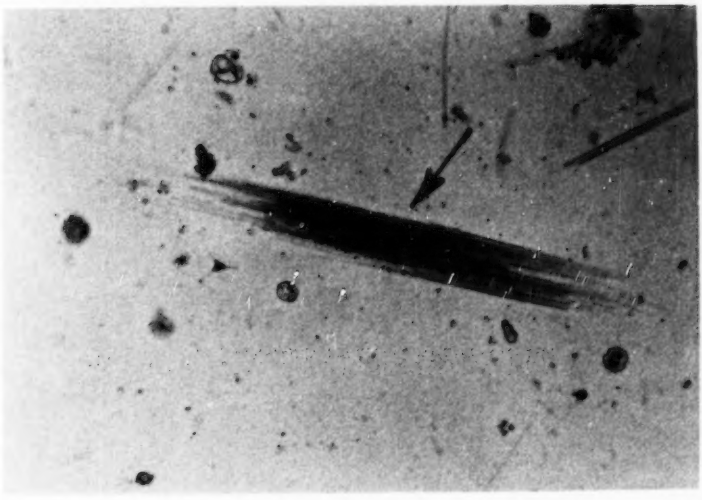

Fig. 10 Aphanizomenon (120 X)

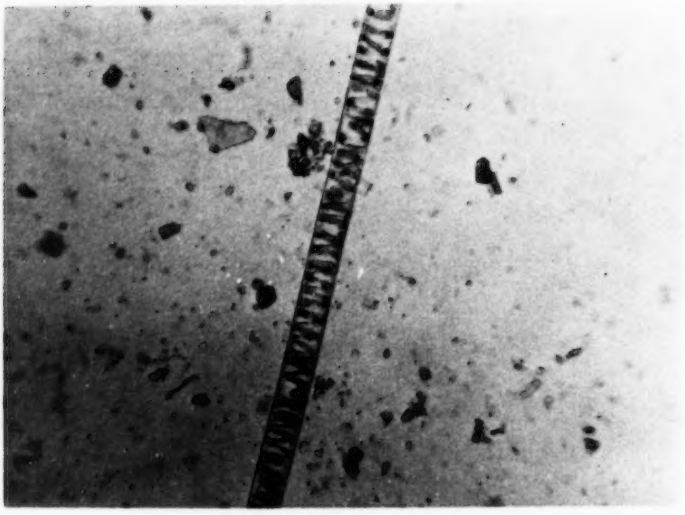

Fig. 11 Spirogyra (120 X)

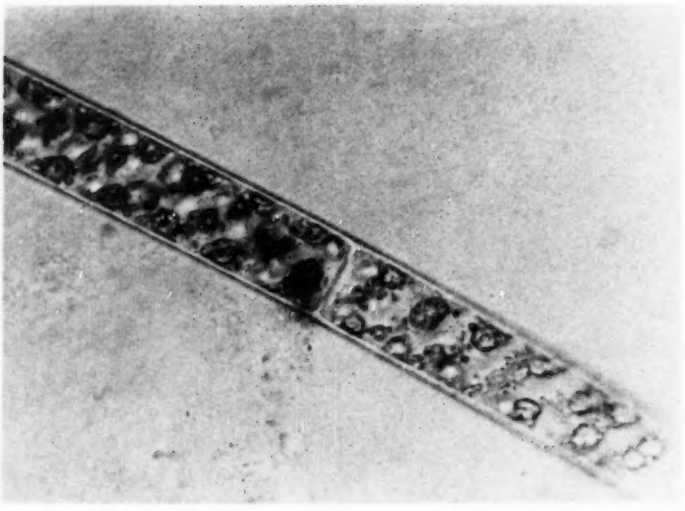

Fig. 12 Spirogyra (280 X)

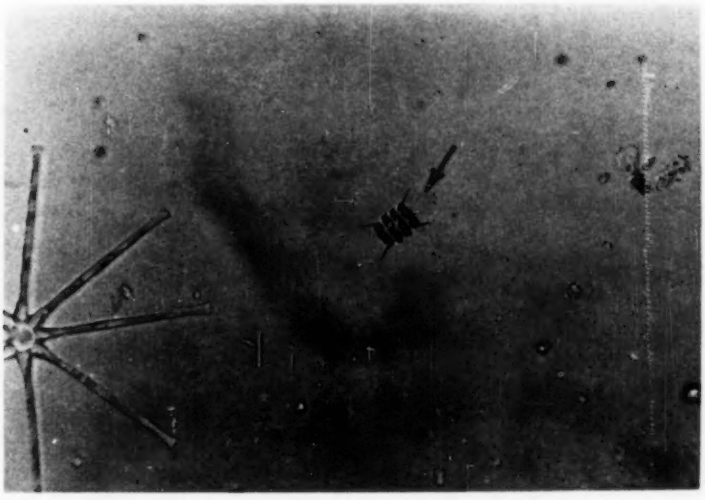

Fig. 13 Scenedesmus (400 X)

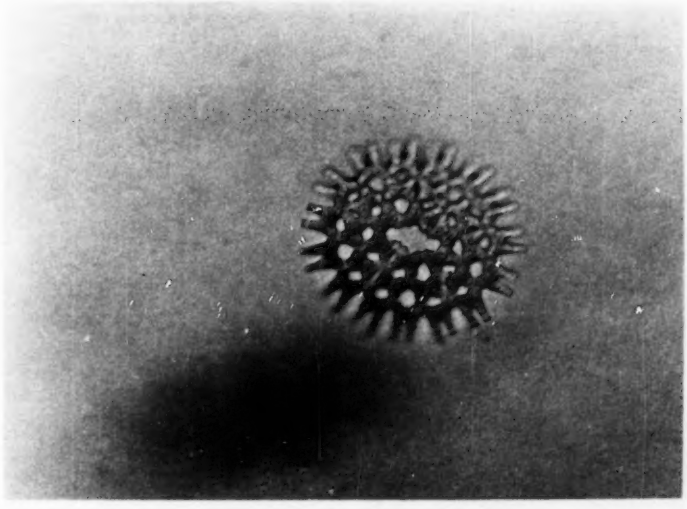

Fig. 14 Pediastrum (400 X)

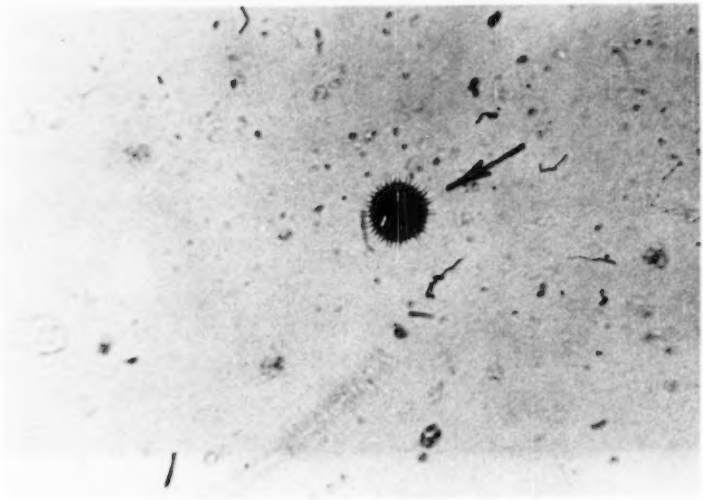

Fig. 15 Pediastrum (100 X)

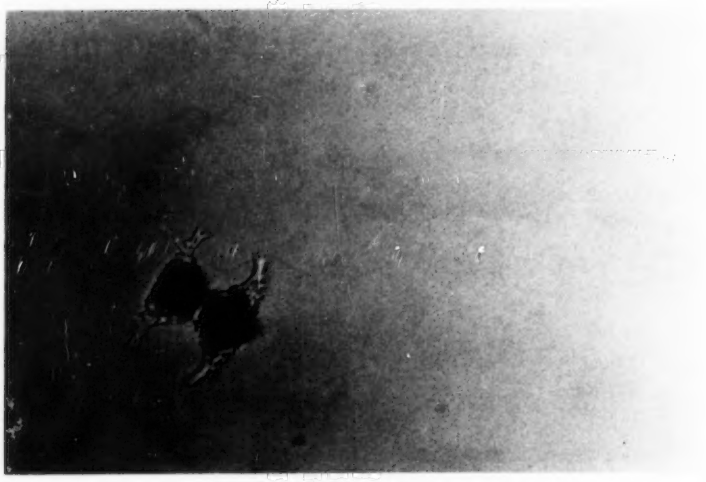

Fig. 16 Staurastrum (400 X)

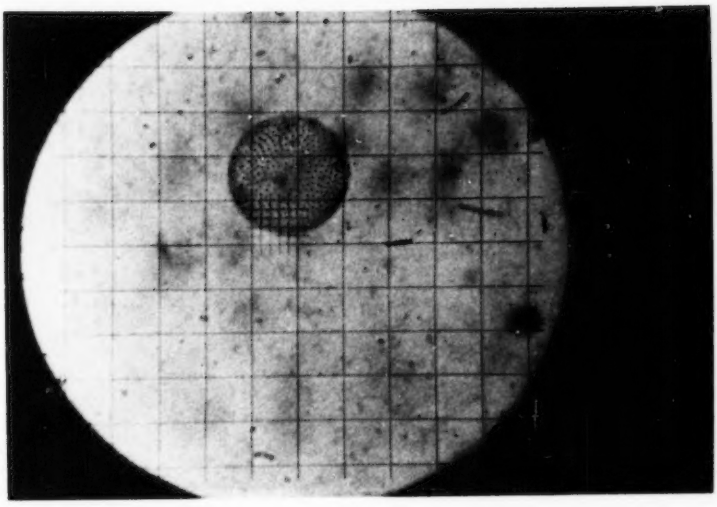

Fig. 17 Volvox (25 X)

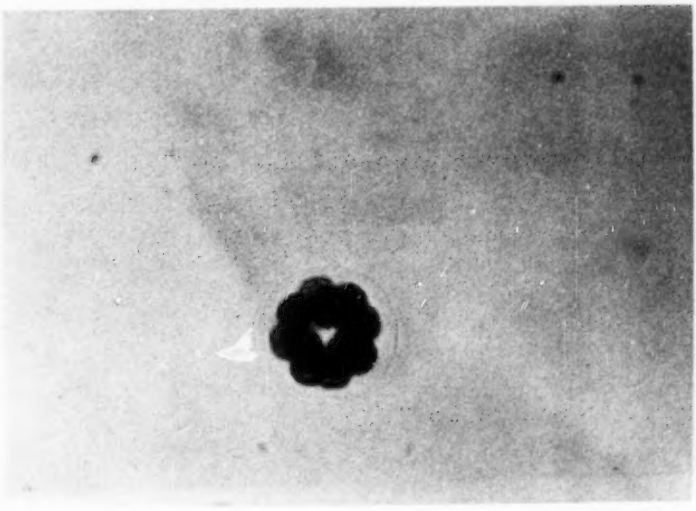

Fig. 18 Pandorina (120 X)

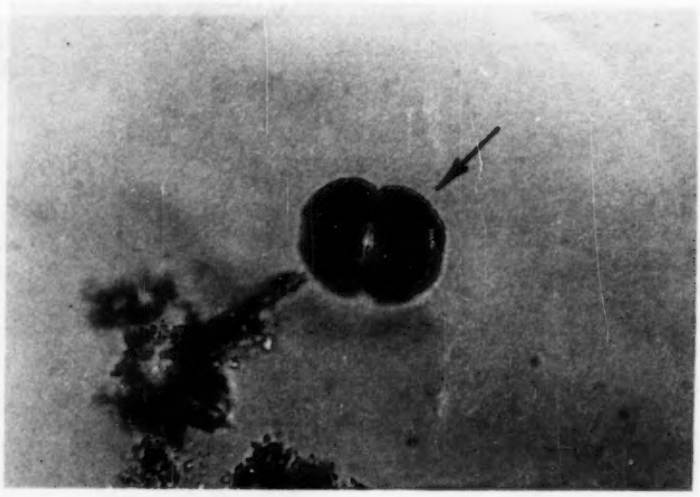

Fig. 19 Cosmarium (200 X)

Fig. 20 Cosmarium (200 X)

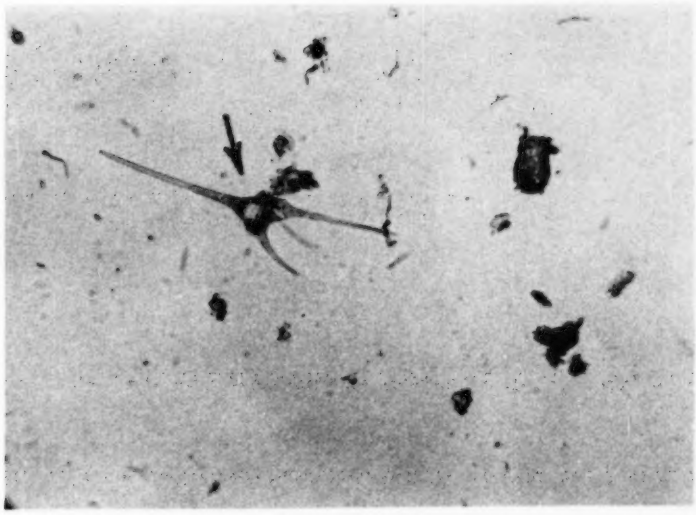

Fig. 21 Ceratium (120 X)

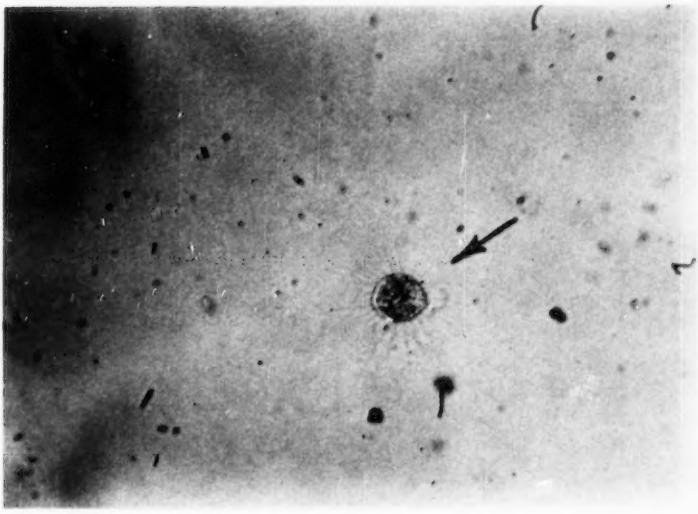

Fig. 22 Actinophyrs (150 X)

Fig. 23 Codonella (200 X)

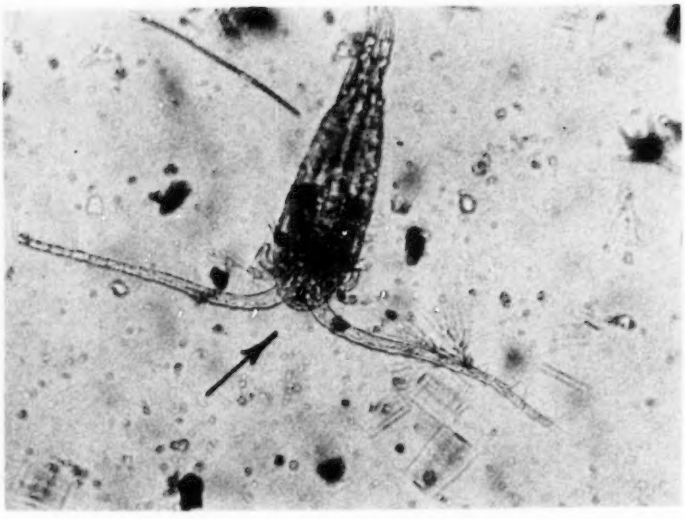

Fig. 24 Cyclops (120 X)

Fig. 25 Daphnia (120 X)

Fig. 26 Method of Applying Copper-Sulfate

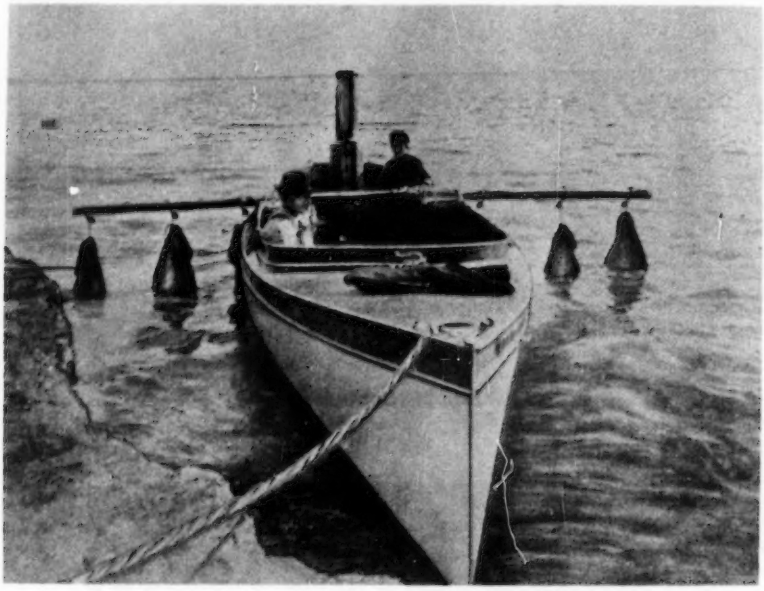

Fig. 27 Method of Applying Copper-Sulfate to a Large Reservoir

AMERICAN SOCIETY OF CIVIL ENGINEERS

OFFICERS FOR 1953

PRESIDENT

WALTER LEROY HUBER

VICE-PRESIDENTS

Term expires October, 1953:
GEORGE W. BURPEE
A. M. RAWN

Term expires October, 1954:
EDMUND FRIEDMAN
G. BROOKS EARNEST

DIRECTORS

Term expires October, 1953:
KIRBY SMITH
FRANCIS S. FRIEL
WALLACE L. CHADWICK
NORMAN R. MOORE
BURTON G. DWYRE
LOUIS R. HOWSON

Term expires October, 1954:
WALTER D. BINGER
FRANK A. MARSTON
GEORGE W. McALPIN
JAMES A. HIGGS
I. C. STEELE
WARREN W. PARKS

Term expires October, 1955:
CHARLES B. MOLINEAUX
MERCEL J. SHELTON
A. A. K. BOOTH
CARL G. PAULSEN
LLOYD D. KNAPP
GLENN W. HOLCOMB
FRANCIS M. DAWSON

PAST-PRESIDENTS

Members of the Board

GAIL A. HATHAWAY
CARLTON S. PROCTOR

TREASURER

CHARLES E. TROUT

EXECUTIVE SECRETARY

WILLIAM N. CAREY

ASSISTANT TREASURER

GEORGE W. BURPEE

ASSISTANT SECRETARY

E. L. CHANDLER

PROCEEDINGS OF THE SOCIETY

HAROLD T. LARSEN
Manager of Technical Publications

DEFOREST A. MATTESON, JR.
Assoc. Editor of Technical Publications

PAUL A. PARISI
Editor of Technical Publications

COMMITTEE ON PUBLICATIONS

LOUIS R. HOWSON

FRANCIS S. FRIEL
GLENN W. HOLCOMB
I. C. STEELE
FRANK A. MARSTON
NORMAN R. MOORE

* Readers are urged to submit discussion applying to current papers. Forty free Separates per year are allotted to members. Mail the coupon order form found in the current issue of *Civil Engineering*.